# Bone Allograft Segment Covered with a Vascularized Fibular Periosteal Flap: A New Technique for Pediatric Mandibular Reconstruction

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## Abstract

The free vascularized fibular graft is nowadays the preferred technique for pediatric mandibular reconstruction. Despite the versatility and proven efficacy for restoring the facial appearance and maxillomandibular function, those mandibular reconstructions with free vascularized fibula associate difficulties for a simultaneous restoration of the alveolar height and facial contour, which are derived from the height discrepancy between the fibula and the native mandible. In addition, the donor-site growth and morbidity are of special concern in the pediatric patient. We report a novel technique for pediatric mandibular reconstruction, in an 11-year-old girl, using a combination of a bone allograft segment with a vascularized fibular periosteal flap (VFPF), after resection of an Ewing sarcoma located at the right body of the mandible. The patient has showed optimal cosmetic, functional, and radiological outcomes, which have been maintained for 2.5 years, without detecting donor-site complications. Through this original technique, and based on the powerful osteogenic and vasculogenic properties of the pediatric VFPFs, we could effectively reconstruct a large mandibular defect providing a functional and aesthetic reconstruction, while avoiding the potential morbidity associated with the fibula resection.

**Keywords**

- mandibular reconstruction
- pediatric mandibular reconstruction
- vascularized periosteal flap
- vascularized fibular periosteal flap

Pediatric mandibular reconstruction is a complex surgical scenario.[1] Several surgical techniques have been described in the past including the use of alloplastic material, regional pediculated flaps, nonvascularized bone grafts (NVBGs), and vascularized composite free flaps. However, the free vascularized fibular graft (FVFG) has become the preferred technique for reconstructions of large mandibular defects in both adults and children.[1,2]

Recently, vascularized periosteal flaps have been described for reconstruction of pediatric orthopedic conditions, showing great potential for bone revascularization.[3] We report on the use of a bone allograft segment (BAS) covered

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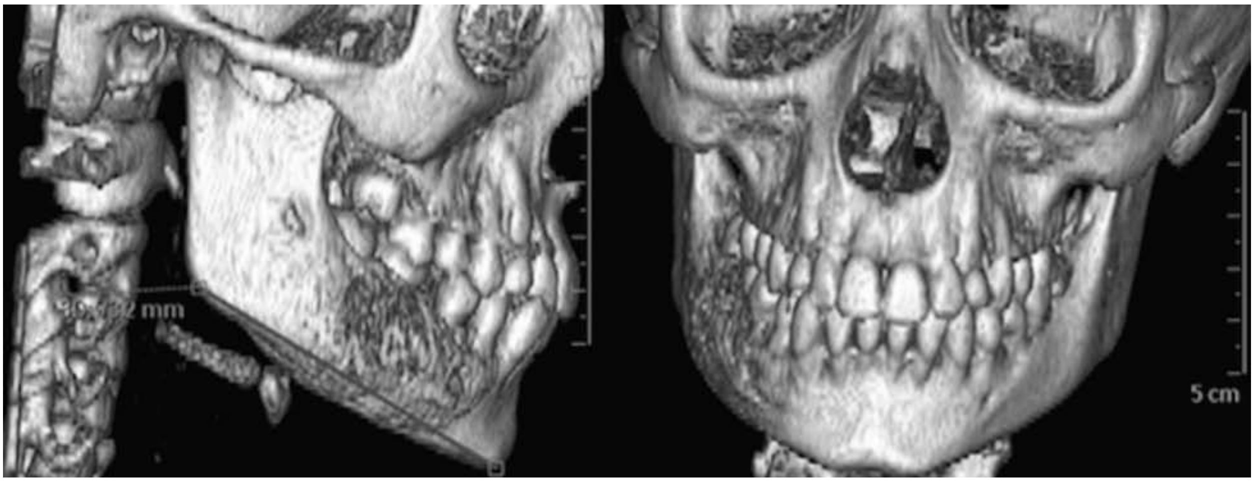

**Fig. 1** Preoperative CT scan showing an Ewing sarcoma located in the right body of the mandible, as an ill-defined lesion with osteolytic changes and erosion of the buccal cortex.

with a vascularized fibular periosteal flap (VFPF) to reconstruct a large mandibular defect in a pediatric patient, with the purpose of simultaneously reconstruct the facial contour and alveolar height, while avoiding the potential morbidity associated with the fibula resection.

## Case Report

A 10-year-old girl was referred to the Pediatric Oral and Maxillofacial Surgery Unit, with a history of persistent painful swelling at the right lower jaw, despite antibiotic therapy. The diagnostic workup revealed a nonmetastatic Ewing sarcoma involving the right body of the mandible, extending from the canine (43) to the second molar (47) (►**Fig. 1**). The patient underwent standard treatment with chemotherapy followed by wide surgical resection and immediate reconstruction.

Tumor resection and VFPF harvest were performed simultaneously. A segmental mandibulectomy was performed intraorally, from the level of the right lateral incisor to the right angle measuring 6.2 cm in length, extending to the surrounding soft tissues to achieve adequate surgical margins. No skin resection was performed because it was not macroscopically infiltrated. The resection margins were free of tumor on the frozen section and also on the definitive histopathological analysis.

A cadaveric mandible with equivalent shape and dimensions to those of the patient was selected preoperatively from the tissue bank. After performing the resection, two osteotomies were performed on the cadaveric mandible to obtain a BAS that matched the surgical defect: one at the right parasymphysis and one at the upper right angle. The single-piece BAS measured 6.2 cm in length and 2.3 cm in height. Bone fixation was performed with osteosynthesis titanium miniplates and screws (Synthes Matrix Mandible, Synthes, West Chester, PA). The recipient vessels were isolated through a submandibular approach, and the VFPF was harvested from the left leg according to the surgical technique described by the senior author (F.S.) (►**Fig. 2**).

The VFPF harvesting technique follows most of the standard steps used to raise a FVFG with specific technical modifications. Instead of performing osteotomies, the fibular periosteum is incised longitudinally, following the lateral aspect of the fibular shaft, and then circumferentially in the distal fibula. The peroneal vessels are then ligated distally and the periosteal flap is elevated from distal to proximal with the use of a periosteal elevator. This step allows a progressive detachment of the tibialis posterior muscle, leaving a thin muscle cuff to preserve periosteal vascularity. Finally, a proximal release of the periosteum at the level of the fibular neck is performed, with dissection of the pedicle up to its takeoff from the posterior tibial vessels to gain as much of pedicle length as required.

Once harvested, the VFPF (9 cm × 3 cm) was positioned, with the cambium layer facing the bone, over the reconstructed hemimandible ensuring coverage of host bone—BAS junctions (►**Fig. 3**). The elasticity of the flap allowed coverage of the superior, external, and basal surfaces of the reconstruction. Absorbable sutures were used to stabilize the flap. The

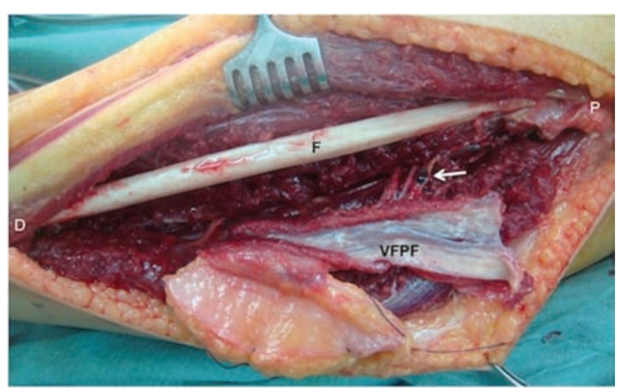


**Fig. 2** Intraoperative figure. The VFPF was harvested from the left leg with a skin pad. The flap was still connected to the fibular vessels (arrow). D, distal; F, fibula; P, proximal; VFPF, vascularized fibular periosteal flap.

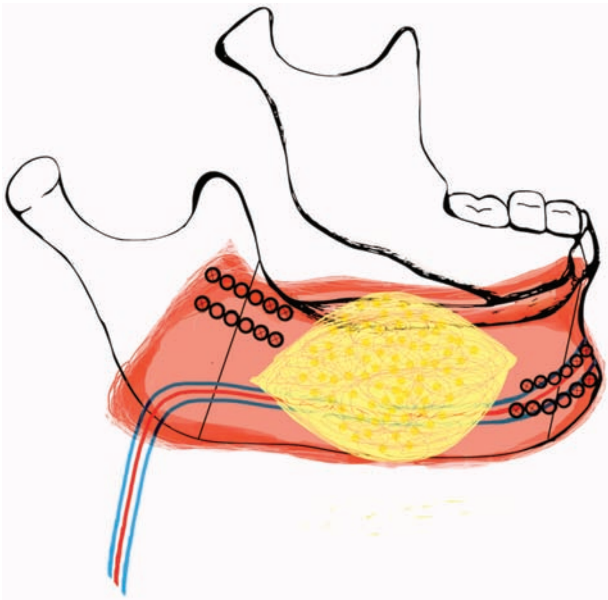

**Fig. 3** Schematic depiction of the final reconstruction. The VFPF is placed over the reconstructed defect, covering the superior, lateral, and inferior surfaces including the host bone—BAS junctions. The de-epithelized cutaneous island was used for soft tissue augmentation of the cheek. BAS, bone allograft segment.

cutaneous island was de-epithelized for soft tissue augmentation of the cheek because direct mucosal closure was judged to be feasible. The VFPF vessels were anastomosed to the facial artery and vein. A second venous anastomosis was performed to the lingual vein.

Postoperatively, the vascular status of the VFPF was checked by Doppler ultrasound monitoring, coupled with close clinical follow-up. No early postoperative complications were detected at the recipient and donor sites. The patient was maintained on postoperative antibiotic therapy with amoxicillin/clavulanic acid for 2 weeks, until verification of mucosal wound healing, and she was allowed to ambulate using a walking splint for the first 3 postoperative weeks. No adjuvant radiotherapy was indicated because the surgical margins were reported as adequate on the definitive histopathological analysis.

Revascularization and progressive integration of the allograft were confirmed by means of a single-photon emission computed tomography/computed tomography scan performed at postoperative month 6, showing intense bone uptake (►**Fig. 4**). Panoramic radiographs during follow-up showed complete consolidation of the BAS—host bone interphases (►**Fig. 5**). A preprosthetic remodeling of the alveolar ridge and vestibular mucosa was performed at postoperative month 18 to improve adaptation of the mucous retained dental rehabilitation. A bone spicule from the grafted area was removed showing adequate integration of the BAS on the histologic analysis.

The patient developed a temporary contraction of the flexor hallucis longus with complete recovery within the first 6 postoperative months after conventional physical therapy. Last seen 2.5 years after surgery, our patient remained free of donor-site complications with an overall satisfactory aesthetic outcome as judged by family members and surgeons (►**Fig. 6**). Mandibular dynamics were progressively normalized during follow-up achieving a functional reconstruction with removable dentures; however, an implant-supported denture is planned to be performed, after stabilization of facial growth. The patient and her family report good self-esteem and optimal social interactions.

## Discussion

We describe a technique for pediatric mandibular reconstruction using a BAS covered by a VFPF to reconstruct a large mandibular defect. Our technique was successful achieving revascularization, integration, and consolidation of the BAS, and provided a functional and aesthetic mandibular reconstruction that avoided the potential complications of the fibula resection in a growing patient.

The osteocutaneous FVFG has become the workhorse for segmental mandibular reconstruction.[4] It provides a long bicortical bone that allows multiple osteotomies and the application of dental implants, offering satisfactory functional and esthetic reconstructions. Moreover, the use of the FVFG in children has progressively gained popularity for mandibular reconstructions of large oncological resections and severe facial deformities of the lower jaw.[1,2,5] Despite its advantages, the FVFG handicaps result from the reduced height of the fibula (~10 mm), which is suboptimal for achieving a simultaneous reconstruction of the facial contour and alveolar height.[4] Several technical modifications and secondary procedures have been described to overcome the limitations of the FVFG in terms of bone height such as double-barrel designs and vertical distraction, among others. In contrast, our technique provided enough bone stock to maintain the lower facial contour while reducing the vertical distance to the occlusal plane, thus, facilitating the dental prosthetic rehabilitation.

Before the development of microsurgery, segmental mandibular reconstruction involved the use of NVBGs.[2,4] Although this reconstructive approach might offer optimal outcomes when used for small defects (< 5–6 cm), it requires an adequate soft tissue bed with preservation of the periosteum to optimize the biologic conditions for revascularization of the graft.[6] Similar considerations have been suggested for BAS reconstructions which offer advantages in comparison with autologous NVBGs such as the excellent anatomic matching, the avoidance of donor-site morbidity, and the greater tissue availability.[7,8] van Gemert et al[6] analyzed the use of NVBGs in segmental mandibular reconstruction and reported that the nonvascularized iliac crest offers variable success rates (46–100%) and associates high rates of graft infection (20–35%) leading to revision or failure. Among the few reports on mandibular reconstructions using BASs, Kolesov et al[7] and later Plotnikov and Sysoljatin[8] showed successful results in 90 and 82%, respectively, but they failed to provide discriminated data in relation to size, location, and etiology of the defects reconstructed. Nevertheless, the authors stressed that the quality and the quantity of the

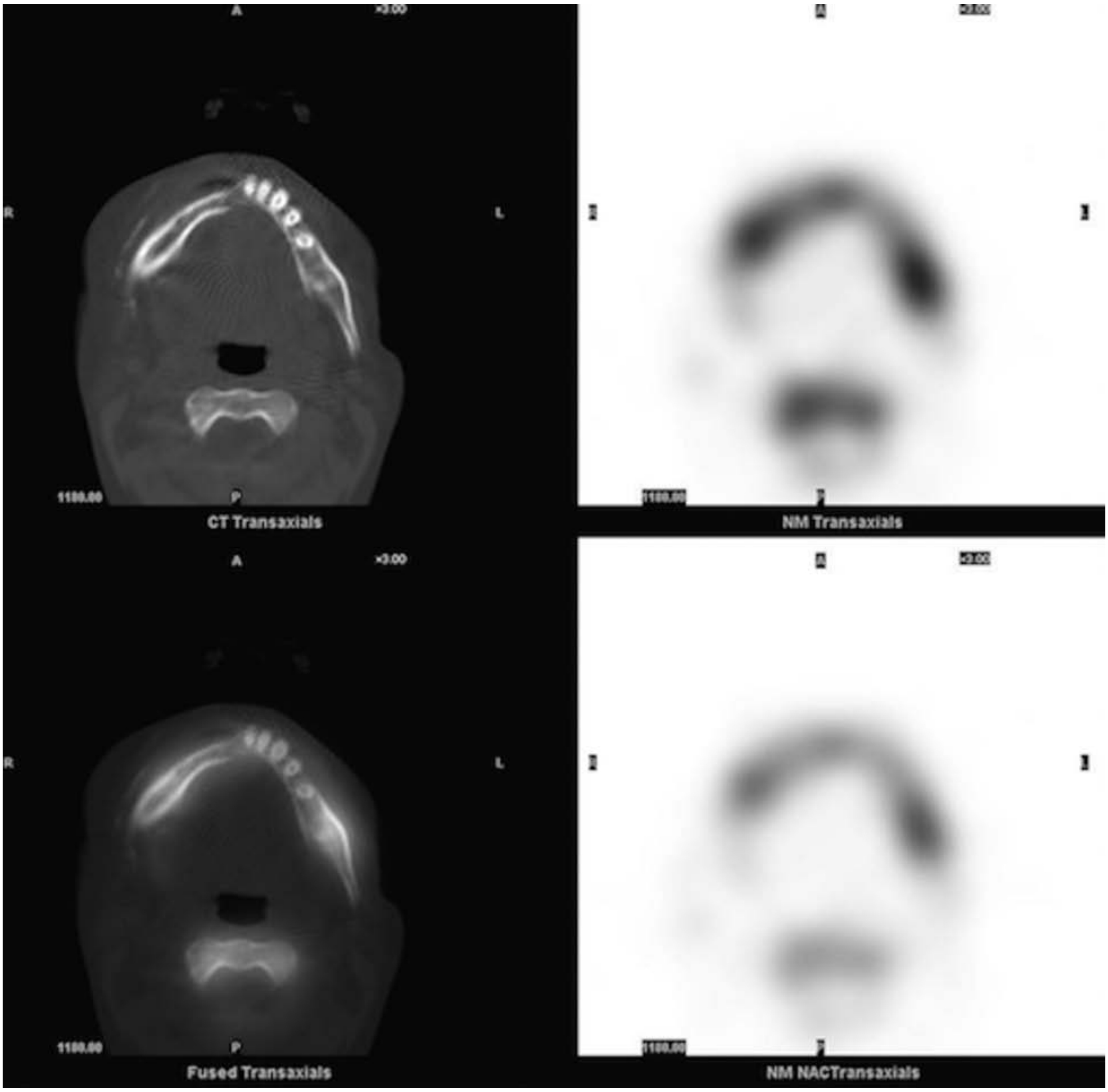


**Fig. 4** SPECT-CT performed at postoperative month 6, showing osteogenic activity of the BAS used for mandibular reconstruction. BAS, bone allograft segment; SPECT, single-photon emission computed tomography-computed tomography.

soft tissue coverage were the key points for success of segmental mandibular reconstructions using BASs.[9] With our technique, we have been able to reconstruct a large bony defect measuring 6.2 cm in length and, as recommended for mandibular reconstructions with NVBGs, the VFPF provided an adequate recipient site with the necessary biologic support for revascularization and integration of a large BAS.

Every transplanted bone graft undergoes remodeling with resorption as part of the normal process of integration; however, NVBGs show greater resorption rates than vascularized bone grafts.[9,10] In our patient, the follow-up imaging has shown minimal BAS resorption of the lower aspect of the distal reconstruction; however, the facial contour remains stable in the clinical examination, the alveolar ridge remains leveled with the native jaw, and the BAS height remains greater than the average height provided by the fibula in FVFG reconstructions. In addition, the BAS reconstruction is tridimensionally equivalent to the resected segment, which has facilitated the design and adaptation of the temporary mucous-retained dentures over the alveolar ridge (►**Fig. 7**). The integration and overall stability of the BAS reconstruction can be explained by the biologic support provided by the pediatric VFPF.

Vascularized periosteal grafts have been recently described in pediatric orthopedic surgery and have showed great potential for bone revascularization. This type of free flaps has been described for the treatment of established recalcitrant bone nonunion, and also, for the prevention of nonunion of BASs used for segmental limb reconstructions.[3] Properties of the pediatric VFPF include its ease of harvesting

**Fig. 5** Panoramic radiograph showing complete consolidation of the BAS—host bone interphases. A minimal resorption of the graft can be seen. BAS, bone allograft segment.

and its great elasticity, which allowed us to adapt the flap over the reconstruction including both bone junctions. However, the main attribute of the pediatric VFPF is the rich content of stem cells located at the cambium layer, which provide excellent osteogenic and angiogenic properties that biologically support bone healing and revascularization.[3] As a result, we have been able to provide an adequate soft tissue envelope with the necessary biologic properties to achieve integration and consolidation of a large BAS as demonstrated by clinical, radiological, and histological examination. The combination of a BAS with the VFPF provided an osteoconductive, osteoinductive, and osteogenic type of reconstruction that has integrated successfully. Dental implants will be installed at completion of facial skeleton growth and, taking into account the above, we expect these to integrate uneventfully.

The intraoperative and postoperative donor-site morbidity of the VFPF technique is similar to that reported for the FVFG. Several authors have reported on the use of FVFGs for pediatric mandibular reconstruction without associated ankle morbidity.[1,2,5] However, most of these remain short series of patients with limited follow-up. Moreover, Sulaiman et al evaluated the long-term effects on the foot and ankle following FVFGs in

**Fig. 6** View of the patient 2 years after surgery showing optimal aesthetic outcomes, with restoration of the facial contour.

**Fig. 7** Intraoral view of the patient 2 years after surgery showing adequate height of the alveolar crest at the reconstructed side of the mandible. Severe dental decay has followed oncological and surgical treatment.

children and concluded that resecting the fibula, even with preservation of a 6-cm distal fibular stump, may lead to abnormal growth in children younger than 6 years old. In this regard, an additional advantage of our technique is the avoidance of the potential ankle instability and valgus deformity associated with the fibula resection.[11] In addition, by preserving the entire fibula, the longitudinal growth of the fibula is likely to be maintained because the proximal and distal fibular physes are preserved together with the epiphyseal periosteal and endosteal vessels. In fact, after a temporary contraction of the flexor hallucis longus, our patient has shown optimal lower limb function and growth remains symmetrical.

Weak points of our article are intrinsic of being a case report; nevertheless, the novel technique has showed promising results. We have been able to provide an anatomical and functional mandibular reconstruction after a large composite resection of the mandible, while the potential morbidity associated with the fibula resection has been avoided. We think that this technique could be of interest for segmental mandibular reconstructions in children suffering from mandibular defects after large tumor resections, and also in cases of hemifacial microsomia. Further cases are needed to delineate the benefits and disadvantages of this reconstructive technique.

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